DOE Office of Petroleum Reserves – Strategic Unconventional Fuels

Fact Sheet: Energy Efficiency of Strategic Unconventional Resources

The Issues

- The three primary sources of energy are fossil hydrocarbons, nuclear, and solar in its various forms.
- Nuclear and solar are best suited for making electricity; fossil hydrocarbons are best suited for producing liquid fuels.
- Energy *production efficiency* is declining, reflecting the greater difficulty in recovering and converting energy to end-use forms.
- Reduced production efficiency increases economic costs and increases environmental impacts. These provide dual incentives to increasing the efficiency of primary production.

Definitions of Efficiency

- A rigorous, well-accepted method for calculating efficiency utilizes the "first-law of thermodynamics", which says:

  First-Law Energy Efficiency = energy output / energy input (expressed as a percent),

- Another useful measure is the Energy Return on Investment (EROI) which says:

  EROI = (energy output – energy consumed) / energy consumed

- The EROI deducts the energy consumed in the process to yield the net energy produced. The higher the number, the greater the energy return for the energy invested in the process.

Efficiency of Fossil Fuels Production

- Recovering oil from gushers in the early years of the petroleum industry required only the energy to drill the wells. Flush production was followed by pump jacks followed by enhanced oil recovery followed by exploration and development in increasing hostile environments, all of which increased energy use. Today, the world has cumulatively produced about 1 trillion barrels of conventional oil. In this process, the first-law energy efficiency has fallen from the high 90's to about 92% today (see Figure 1).
- Unconventional fuels require additional processing steps (mining, heating, upgrading) to recover and convert these resources to fuels. These steps consume energy and lower the energy efficiency relative to conventional oil.
- Experience with the Alberta oil sands show that energy efficiency improves as the industry matures and operations improve. The average efficiency of oil sands development has improved to about 82% from the low 70's in first generation facilities. (See Figure 2).
- U.S. oil shale is richer in energy content than the Alberta oil sands. Therefore, the first-law energy efficiency for oil shale will be greater than for oil sands.
- All fossil resources will become more difficult to produce as the highest grade and most accessible deposits are produced. Additional energy will therefore be required to produce each incremental barrel. This will continue to lower energy efficiency for all conventional and unconventional fossil resources.

Figure 1. Energy Efficiency vs. Cumulative Production

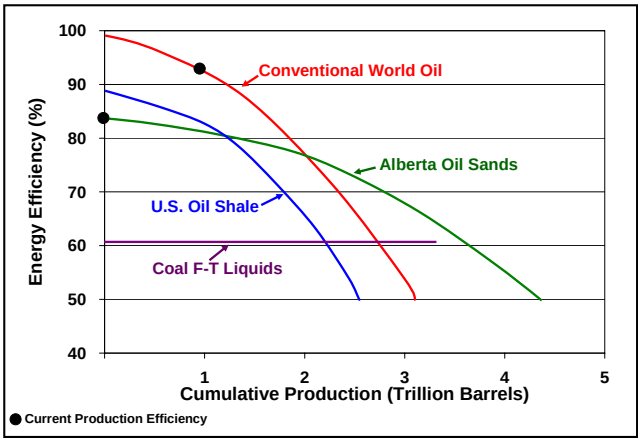
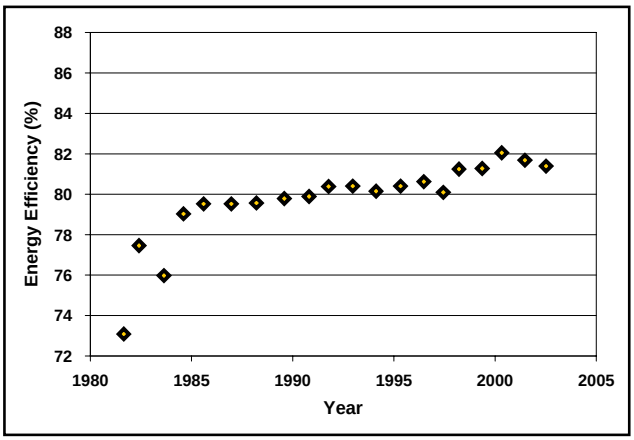


Figure 2. Oil Sand Efficiency Increases over Time



Calculated Efficiencies for Liquid Fuels Production

Energy efficiency and energy return on investment are summarized for various resources in Figure 3. In this calculation *only the external energy imported to the process* is used to calculate the EROI.

During initial development, conventional world oil had energy efficiency in the high 90 percent range and a EROI of 20 or more. The energy cost of deep drilling, secondary recovery, enhanced oil recovery, and the production of higher viscosity oil has reduced the energy efficiency to about 92% and the EROI to about 10.

As compared with conventional oil, all unconventional supply options have significantly lower energy efficiency and a lower EROI.

Table 1. Energy Efficiency Estimates

Resource and Process	First-Law Energy Efficiency, %	EROI, Value
Conventional petroleum E&P	92	10.5
U.S. Oil Shale (Surface)	82	>10.0
Alberta Oil Sands (Surface)	82	7.2
Alberta Oil Sands (in-situ) (similar to heavy oil)	86	5.0
U.S. Oil Shale (in-situ, non-electric heat)	89	6.9
U.S. Oil Shale (in-situ, electric heat)	78	2.5
Coal IGCC with FT synthesis	65	6.0
Ethanol from Corn (after Wang)	52	< 1.0

Source: James W. Bunger Associates, 2006.

Conclusions

- The United States must diversify its fuel supply and improve the efficiency of fuel use to meet increasing energy supply and demand challenges and to strengthen our nation's energy security.
- Fortunately, the nation has several trillion barrels of unconventional resources that can contribute to diversifying supply and increasing domestic production
- Unconventional fuels alone, however, will be insufficient to significantly *reduce* the nation's dependence on imports – improvements in end-use efficiency will also be needed to reduce liquid fuels demand.
- More energy will be required to produce fuels from unconventional resources than was required in the era of easy oil. However, unconventional fuels can be produced with substantial positive net energy gains.

> *"So long as oil is used as a source of energy, when the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil, production will cease no matter what the monetary price may be."*
>
> -- M. King Hubbert
> (as Referenced by Ivanhoe, 1982).